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Development of an operator-machine interface for ELVISS

Final report

Sharon McFadden
DRDC Toronto

Jacquelyn Crebolder
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Technical Report
DRDC Toronto TR 2006-057
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Principal Author

Original signed by Sharon M. McFadden

Sharon M. McFadden

Human Factors Research and Engineering Section

Approved by

Keith Hendy

Head, Human Factors Research and Engineering Section

Approved for release by

K. M. Sutton

Chair, Document Review and Library Committee

Abstract

DRDC Valcartier has developed a multi-sensor surveillance system composed of an active imaging system (the Airborne Laser-Based Enhanced Detection and Observation System (ALBEDOS)) and a thermal Infrared (IR) imaging system. This system is called the Enhanced Low-light level Visible and Infrared Surveillance System (ELVISS). The purpose of the system is to enhance surveillance capability at night and under degraded weather conditions especially for Search and Rescue (SAR) operations. Throughout the development process, DRDC Toronto was responsible for the design of the Operator-Machine Interface (OMI) for ELVISS. This report summarizes the development of the OMI carried out under Work Unit 13da22, Operator Machine Interface (OMI) for ELVISS. The emphasis is on ELVISS' current state and includes recommendations for research and development that would further enhance the ability of the system to support SAR operations.

Résumé

RDDC Valcartier a mis au point un système de surveillance multi-capteurs composé d'un système d'imagerie active (système laser aéroporté perfectionné de détection et d'observation [ALBEDOS]) et d'un système d'imagerie infrarouge thermique. Ce système, appelé système perfectionné de surveillance à intensification de lumière visible et à infrarouge (ELVISS), sert à améliorer la capacité de surveillance la nuit et dans de mauvaises conditions météorologiques, en particulier pour les opérations de recherche et sauvetage (SAR). Au cours de la mise au point, RDDC Toronto s'est chargé de la conception de l'interface opérateur-machine (OMI) du système ELVISS. Le présent rapport résume la mise au point de l'OMI effectuée en vertu de l'unité de travail 13da22, l'interface opérateur-machine (OMI) du système ELVISS. Le rapport met l'accent sur l'état actuel du système ELVISS et comprend des recommandations concernant les travaux de recherche et développement qui permettraient d'augmenter la capacité du système à prendre en charge des opérations SAR.

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Executive summary

Development of an operator-machine interface for ELVISS

McFadden, S.M., Crebolder, J.M., Larochelle, V.; DRDC Toronto TR 2006-057; Defence R&D Canada – Toronto; March 2006.

DRDC Valcartier has developed a multi-sensor surveillance system composed of an active imaging system (the Airborne Laser-Based Enhanced Detection and Observation System (ALBEDOS)) and a thermal Infrared (IR) imaging system. This system is called the Enhanced Low-light level Visible and Infrared Surveillance System (ELVISS). Its purpose is to enhance surveillance capability at night and under degraded weather conditions especially for Search and Rescue (SAR) operations. Throughout the development process, DRDC Toronto was responsible for the design of the Operator-Machine Interface (OMI) for ELVISS. The development of the OMI involved (i) a human factors analysis of the ALBEDOS interface, (ii) the development of a list of tasks associated with the operation of ALBEDOS and ELVISS in the SAR environment, (iii) the development of design concepts for ALBEDOS and ELVISS, (iv) the development of a software prototype of the OMI to evaluate the proposed design concepts, and (v) the development of a hardware prototype with an OMI based on the design concepts. Unfortunately, technical limitations precluded a human factors assessment of the hardware prototype.

This report summarizes the development of the OMI carried out under Work Unit 13da22, Operator Machine Interface (OMI) for ELVISS. The overriding goals in the development of the interface were to make it as intuitive as possible and to incorporate suitable automation and decision support to reduce the requirement to manually adjust system parameters. As well, the interface should provide the operator with information about where the sensors are looking and what they are looking at. Based on human factors evaluations conducted with the ELVISS software prototype, the OMI does represent a significant improvement over the ALBEDOS interface. If the technical limitations can be overcome, a system with the technical capabilities of ELVISS and an OMI based on the design concepts summarized in this report should improve the search and identification capabilities of the SAR specialist especially at night and in inclement weather.

The report's emphasis is on the current state of the OMI and includes the following recommendations that should further enhance the ability of the system to support SAR operations:

- operator access to menu items with either the function keys or the trackball;
- incorporation of a continuous pulse mode for the laser rangefinder;
- integration of controls to change the laser illuminator pulse width and the beam diameter;
- development of a display that integrates the sensors' vertical and horizontal direction;
- inclusion of a thermal imager with a wide field of view of a least 20 degrees;

- addition of a rapid zoom out capability on the Active Gated Television (AGTV);
- capability to store and recall a large number of images;
- operator control of the moving map’s brightness.

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Development of an operator-machine interface for ELVISS

McFadden, S.M., Crebolder, J.M., Larochelle, V.; DRDC Toronto TR 2006-057; R & D pour la défense Canada – Toronto; March 2006.

RDDC Valcartier a mis au point un système de surveillance multi-capteurs composé d'un système d'imagerie active (système laser aéroporté perfectionné de détection et d'observation [ALBEDOS]) et d'un système d'imagerie infrarouge thermique. Ce système, appelé système perfectionné de surveillance à intensification de lumière visible et à infrarouge (ELVISS), sert à améliorer la capacité de surveillance la nuit et dans de mauvaises conditions météorologiques, en particulier pour les opérations de recherche et sauvetage (SAR). Au cours de la mise au point, RDDC Toronto s'est chargé de la conception de l'interface opérateur-machine (OMI) du système ELVISS. La mise au point de l'OMI a comporté les étapes suivantes : (i) analyse des facteurs humains de l'interface ALBEDOS; (ii) élaboration d'une liste de tâches associées au fonctionnement des systèmes ALBEDOS et ELVISS dans le milieu SAR; (iii) formulation des principes de conception des systèmes ALBEDOS et ELVISS; (iv) mise au point d'un prototype de logiciel de l'OMI en vue de l'évaluation des principes proposés de conception; et (v) mise au point d'un prototype de matériel doté d'une OMI fondée sur les principes de conception. Malheureusement, des limites techniques ont empêché la réalisation d'une analyse des facteurs humains du prototype de matériel.

Le présent rapport résume la mise au point de l'OMI effectuée en vertu de l'unité de travail 13da22, l'interface opérateur-machine (OMI) du système ELVISS. Les objectifs primordiaux de la mise au point de l'interface étaient de rendre l'interface aussi intuitive que possible et d'y intégrer une automatisation et un soutien à la décision appropriés, afin de réduire le matériel requis pour le réglage manuel des paramètres du système. En outre, l'interface doit donner à l'opérateur de l'information sur la direction dans laquelle les capteurs sont orientés et ce qu'ils visent. D'après les évaluations des facteurs humains menées au sujet du prototype de logiciel du système ELVISS, l'OMI représente vraiment une amélioration significative par rapport à l'interface du système ALBEDOS. Si les limites techniques peuvent être surmontées, un système ayant les capacités techniques du système ELVISS et une OMI fondée sur les principes de conception résumés dans le présent rapport permettra d'améliorer les capacités de recherche et d'identification du spécialiste SAR, en particulier la nuit et par mauvais temps.

Le rapport met l'accent sur l'état actuel de l'OMI et comprend les recommandations qui suivent, qui devraient permettre d’augmenter la capacité du système à prendre en charge des opérations SAR :

- accès de l'opérateur aux articles de menu à l'aide des touches de fonction ou de la boule de commande;
- intégration d'un mode d'émission par impulsions en continu pour le télémètre laser;
- intégration des commandes pour permettre la modification du diamètre du faisceau et de la largeur de l'impulsion d'illumination du laser;

- mise au point d'un affichage qui intègre l'orientation verticale et horizontale des capteurs;
- inclusion d'un imageur thermique ayant un grand champ de vision d'au moins 20 degrés;
- ajout d'une capacité de zoom arrière rapide au capteur de télévision commandée par portes actives (AGTV);
- capacité de stockage et de rappel d'un grand nombre d'images;
- commande, par l'opérateur, de la luminosité de l'affichage cartographique dynamique.

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Acknowledgements

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Introduction

Air-to-ground surveillance (search, detection, and identification) is an important component of many Canadian Forces (CF) operations. Search and Rescue (SAR) specialists search thousands of square kilometres each year in an effort to locate missing aircraft, boats, and people. As well, military personnel conduct surveillance operations to provide commanders with the information needed to support mission planning and execution. Whatever the nature of the surveillance mission, its probability of success is strongly dependent on the ability to search under a wide range of environmental conditions and over all types of terrain. Up to now, the effectiveness of human observers, even when using passive imaging systems such as low-light level TV systems, thermal imagers, and night-vision goggles, has been severely limited under extreme conditions.

To support operators under extreme environmental conditions and to overcome many of the limitations of currently available sensors, Defence R&D Canada – Valcartier (DRDC Valcartier) designed and developed an Airborne Laser-Based Enhanced Detection and Observation System (ALBEDOS) in the early 1990s [1]. ALBEDOS was an active imaging system based on a pulsed laser diode array illuminator and a range-gated low-light level TV camera. Since the system provided its own source of illumination, it was insensitive to ambient light conditions. Moreover, its range-gating mode excluded the effects of backscattering that arise from haze, snow, or rain present in the sensor's field of view (FOV), making it particularly efficient during overcast nights and in degraded weather conditions. However, it had a relatively narrow FOV. To increase the surveillance and reconnaissance capabilities of ALBEDOS over large areas, a second-generation airborne multi-sensor system was designed that combines the benefits of a range-gated active imager with a high-quality complementary thermal imager. ELVISS, for Enhanced Low-light level Visible and Infrared Surveillance System, consists of an improved version of ALBEDOS and a thermal imager installed in two separate airborne platforms that are slaved together, view the same scene, and are controlled by a single user interface [2]. ELVISS is also equipped with a video tracker, a georeference system, and a laser rangefinder to give accurate geolocation of contacts or targets on the ground.

Throughout the development process, DRDC Toronto was responsible for the design of the Operator-Machine Interface (OMI) for ELVISS under work unit 13da22. ALBEDOS was initially developed for SAR operations although it was anticipated that it would be useful to other agencies conducting surveillance operations (e.g., Coast Guard, police, military reconnaissance). With SAR operations, the user would not be a dedicated sensor operator and thus there was a requirement for a simple intuitive interface.

The development of the OMI involved (i) a human factors analysis of the ALBEDOS interface, (ii) the development of a list of tasks associated with the operation of ALBEDOS and ELVISS in the SAR environment, (iii) the development of design concepts for ALBEDOS and ELVISS, (iv) the development of a software prototype of the OMI to evaluate the proposed design concepts, and (v) the development of a hardware prototype with an OMI based on the design concepts. This report summarizes the results of the development of the interface concepts. The emphasis is on the current state of the interface and recommendations for future development.

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Development of ALBEDOS OMI

The first stage in the project was the development of improved OMI concepts for the airborne active imaging sensor ALBEDOS. The system consisted of a pulsed laser source (illuminator), a range-gated, low-light level TV camera with a zoom lens, and associated electronics to synchronize the laser and the camera gate and to provide a wide selection of gate widths, pulse widths, and delays. The laser illuminator is used to illuminate the scene in a specified direction at a specified distance. The gate of the image intensifier is closed from the start of the laser pulse until twice the time it takes the laser pulse to travel out to the distance specified by an operator. The gate then remains open for a duration corresponding to the distance over which the operator wants the scene illuminated and then closes again. In this way, only the light reflected off objects at the specified range and depth enters the camera. Thus, ALBEDOS not only provides its own source of illumination making it suitable for night operations, but also is rather insensitive to ambient light including backscatter from fog and precipitation. The latter makes it suitable for poor weather conditions. Another benefit of range-gating is the elimination of blooming effects caused by the presence of bright light sources in the sensor's FOV. Finally, the active nature of the system allows for the long range detection of flexible retro-reflective tape, such as can be found on life vests.

ALBEDOS was constructed by Wescam Inc. under contract from DRDC Valcartier through joint funding from the National SAR Secretariat (NSS) and the Department of National Defence (DND) [2]. For this reason, the system was primarily designed for use in air-to-ground search by SAR technicians. The interface for ALBEDOS was an extension of an existing interface used by Wescam for operating a low-light level TV camera in a stabilized platform (Figures 1 & 2). Flight trials with ALBEDOS were carried out in collaboration with the Flight Research Laboratory (FRL) of the National Research Council (NRC) in 1995. The purpose of the trials was to demonstrate the potential of ALBEDOS, evaluate its technical capability in various operational scenarios, and conduct a human factors evaluation.

The human factors evaluation [3] included a heuristic evaluation of the OMI for compliance with MIL-STD-1472D (now MIL-STD-1472F) [4], observation of the operators during the flight trials, and questionnaire-based interviews with SAR experts who participated in the flight trials. The SAR experts carried out several scenarios with the system during flight trials that involved detecting and identifying targets at night.

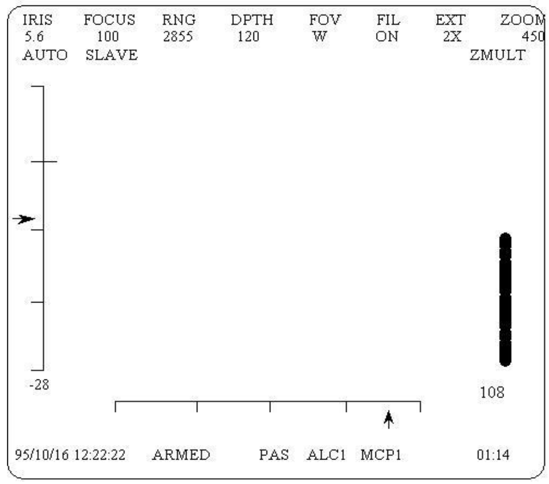

Figure 1. Original display for ALBEDOS. The graphical and alphanumeric information shown was overlaid continuously on the sensor image.

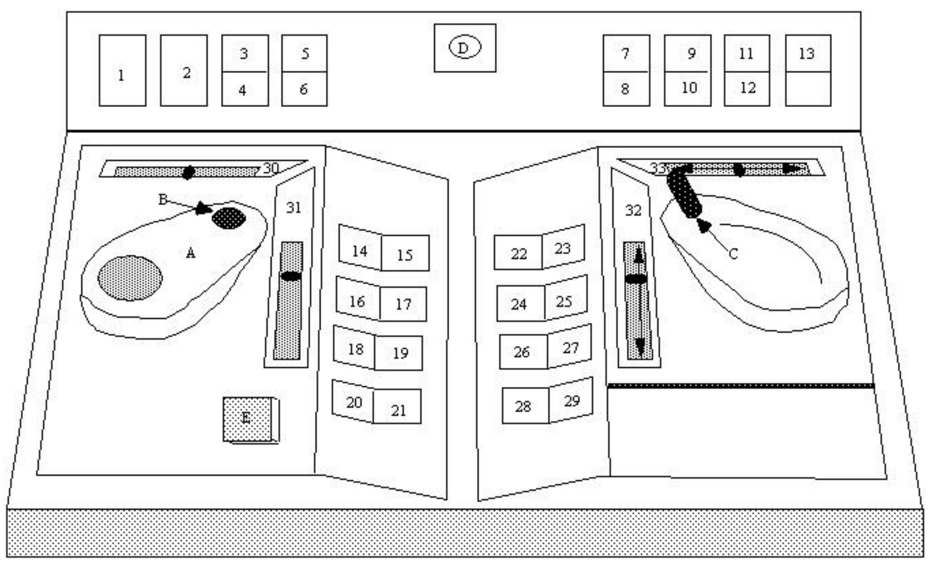

Figure 2. Original ALBEDOS console. The numbered labels appear on the console in the positions indicated. The alphabetic labels are provided to identify the remaining controls. Those labels do not appear on the console.

1. LASER ON/OFF	2. LASER OVER TEMP	3. EXT 1X/2X	4. ZMULT
5. AUTO IRIS	6. FILTER	7. VEH SLAVE	8. VEH SLAVE SET
9. MODE	10. OVERLAY SET	11. GYRO ON	12. RAPID ERECT
13. SYSTEM ON	14. IRIS +	15. IRIS –	16. ALC +
17. ALC –	18. RANGE +	19. RANGE –	20. GATE +
21. GATE –	22. MCP +	23. MCP –	24. ALC AUTO/MAN
25. MCP AUTO/MAN	26. ILLUM FOV	27. FOCUS SLAVE	28. ACTIVE/PASSIVE
29. STATUS	30. IRIS (OPEN-CLOSED)	31. ZOOM (TELE-WIDE)	32. TILT (UP-DOWN)
33. PAN (L - R)	A. Zoom control	B. Focus control	C. Pan and tilt control
D. Key for laser on	E. Emergency switch for laser		

The results of the heuristic evaluation indicated that the interface was not compliant with many of the guidelines contained in MIL-STD-1472 and could interfere with the primary function of ALBEDOS to detect and identify targets. The participants' comments supported that finding. They thought that the system could be useful for identifying targets at night and under degraded weather conditions; however, given the physical and manpower constraints of the SAR environment, the OMI should be simplified and many of the functions automated. Details of the evaluation are described in McFadden and Shek [3]. The report also recommended investigating the addition of the following functions:

- automated determination of the laser illuminator range using a laser rangefinder,
- automated focus control,
- automated tracking function for the camera,
- automated scanning function for setting the gate width,
- automated scanning mode for searching, and
- automated detection function.

As a first step, it was recommended that an existing system and function analysis of SAR operations [5] be extended to determine how a system such as ALBEDOS would be used during SAR operations. The results of this analysis could then be used to evaluate the recommendations arising out of the original human factors evaluation [3] and to prototype a new OMI for ALBEDOS.

As a result of these recommendations, DRDC Toronto was requested to oversee the development of an OMI that would permit SAR personnel to use ALBEDOS effectively and efficiently while carrying out their other duties. CMC Electronics Incorporated (CMC)[1] was contracted to develop design concepts for the OMI to meet that objective. As a starting point, CMC conducted a task analysis as recommended in the ALBEDOS evaluation [3]. The analysis was then used by CMC to develop preliminary design concepts for an interface. CMC reviewed the design concepts with experienced SAR personnel and incorporated their recommendations.

The final step was to implement the proposed design for the ALBEDOS OMI as a rapid prototype[2] using the Virtual Applications Prototyping System (VAPS). Representative controls were provided to meet the overall intent of the design as closely as possible. The prototype simulated most of the existing functionality of ALBEDOS as well as planned improvements including an automatic tracker, a laser rangefinder, the automatic slewing of the sensor to a designated location, and target recording. The model allowed SAR operators to conduct interactive evaluations of the rapid prototype OMI while executing typical search and identification tasks. In terms of the primary objective:

> "the [Subject Matter Experts] SMEs, ALBEDOS Technical Experts and the design team were all satisfied with the final design of the ALBEDOS [Human Machine Interface]

[1] At that time, Canadian Marconi Company, Kanata, ON. Currently, CMC is not an acronym.
[2] A more detailed description of the rapid prototype is given in the next section covering the development of ELVISS.

> HMI. Several comments were received from the SMEs to the effect that the operator interface design was very good, and if this system was currently available in the field it would be a valuable search aid for SAR operations [6](pg 3.21)"

However, the recommendations did reiterate the requirement to provide automated control for many of the functions. For details about the project, the design concepts for the OMI, and the evaluation, see the ALBEDOS Human Engineering Design Approach Document – Operator (HEDAD-O) report by McKay and Kobierski [7].

Development of ELVISS OMI

In parallel with the development of an improved OMI for ALBEDOS, DRDC Valcartier carried out a research and development programme to produce an improved sensor suite. The new system, an Enhanced Low-light level Visible and Infrared Surveillance System (ELVISS), consisted of an improved version of the ALBEDOS active imager (called the Active Gated Television (AGTV) sensor and a thermal infrared (IR) imager, aligned with the AGTV, that was installed on a second stabilized platform [2](Figure 3). Ideally, the two sensors should be mounted on the same platform, but costs and technical challenges led to the decision to use two already existing platforms that were slaved together and controlled by a single interface. The enhancements to the AGTV included a new more powerful laser illuminator that was more covert and allowed greater illumination at its wider FOV and a new zoom lens. The thermal imager complemented the capability provided by the AGTV in that it could be used for the detection of non-reflective objects that have a different thermal profile than the background and that may be obscured by foliage. It provides two discrete FOVs, 2 and 10 degrees, which match the FOVs of the laser illuminator. Unlike the AGTV, it does not have a continuous zoom lens.

Figure 3. The 16- and 24- inch platforms that hold the thermal and AGTV imaging sensors respectively.

In addition, as recommended in the ALBEDOS HEDAD-O [7], ELVISS incorporated a laser rangefinder, a georeference system, and an auto-tracker. The laser rangefinder, installed in the smaller platform along with the thermal imager, was to provide high-resolution range information for the georeference system and determine the best range for the AGTV laser

illuminator. The purpose of the georeference system was to provide precise information on the location of contacts marked on the moving map [2].

Design Concepts for ELVISS interface

Although the sensors were to be mounted in separate platforms, both systems were to be controlled by a single interface. The single interface was important for simplicity, long-term development, and space constraints. In the short term, it was also necessary because the smaller stabilized platform was slaved to the larger one and they had to respond together from a unique command signal. Thus, the interface developed for ALBEDOS was no longer viable. Additional controls were required to operate the thermal imager and an additional window was required to display its output. Work was initiated to develop design concepts for an OMI for ELVISS. The same process was followed as with the ALBEDOS development. The function/task analysis was extended to incorporate the additional functionality; preliminary designs were developed and reviewed by SAR specialists.

The final design concepts proposed by CMC [8] for ELVISS are shown in Figures 4 (display), 5 (multifunction hand controller), 6 (sensor control panel), and 7 (bezel control panel and trackball). In the design for the display, the images from the two sensors are displayed separately on the left side of the screen. Between the two sensor images is a polar plot that provides feedback on the azimuth direction of the sensors relative to the nose of the aircraft. A moving map is located on the right of the screen. Superimposed on the map is an aircraft icon that shows the aircraft's location and direction. A footprint, tethered to the aircraft icon, indicates the area being shown in the sensor image. Screen captures of the sensor images are displayed in the bottom right area of the display. The same area is used to present the menus for accessing system parameters that were not handled by dedicated controls.

The design called for the hand controller, sensor control panel, and trackball to be located on a console in front of the screen and the bezel control panel to be located below the monitor. The hand controller, operated by the right hand, steers the sensors. In addition, it had several buttons and switches to control high priority functions. The sensor control panel was located on the left side of the console. It contained all of the remaining controls required during a search. Controls operated during start-up and shut down only were located on the bezel control panel.

The rationale for the design concepts shown in these figures can be found in the ELVISS HEDAD-O report [8].

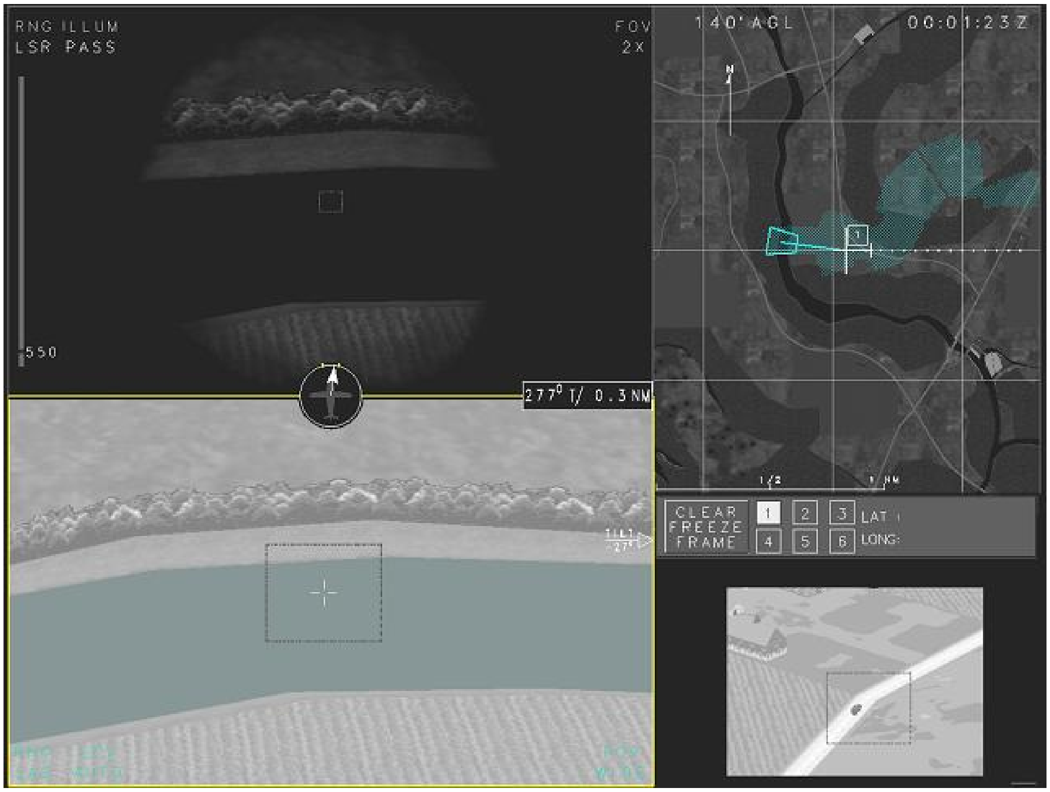

Figure 4. Display proposed for the ELVISS OMI

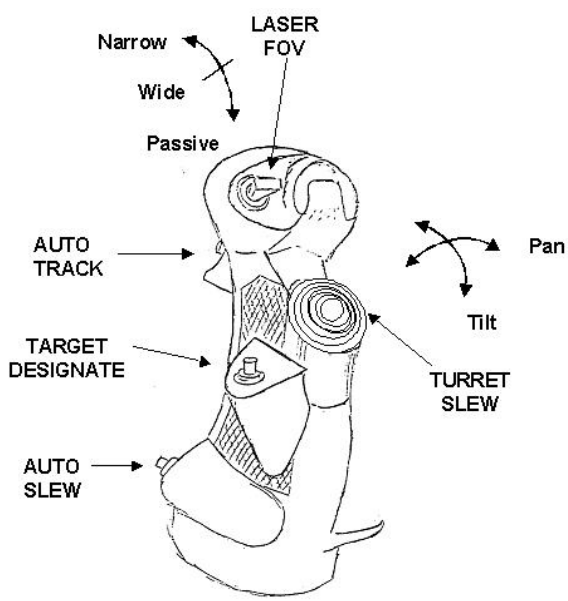

Figure 5. Hand controller proposed for the ELVISS OMI

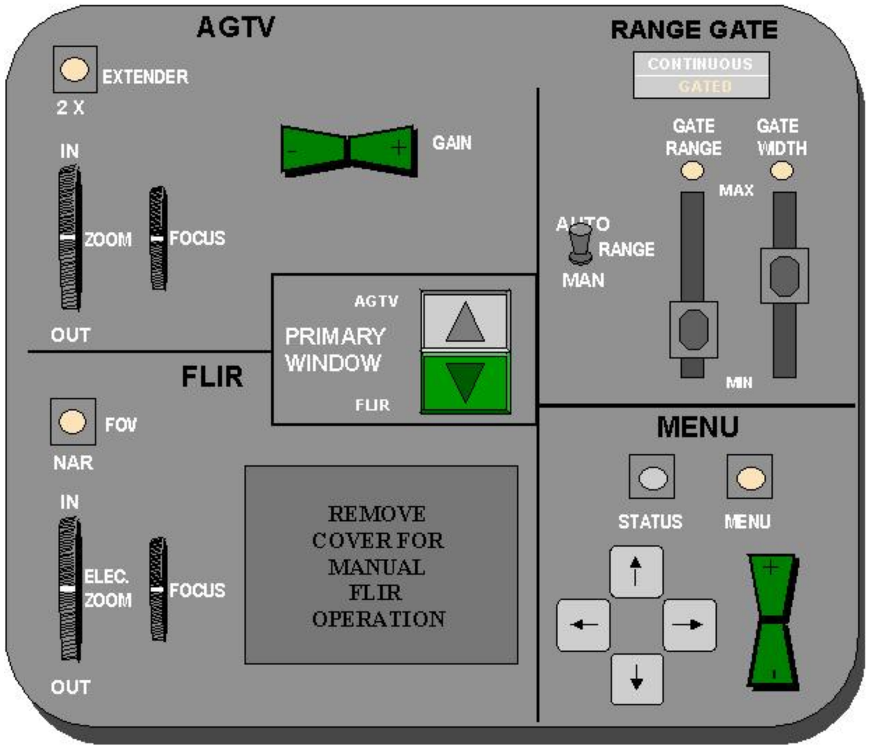

Figure 6. Sensor control panel proposed for the ELVISS OMI

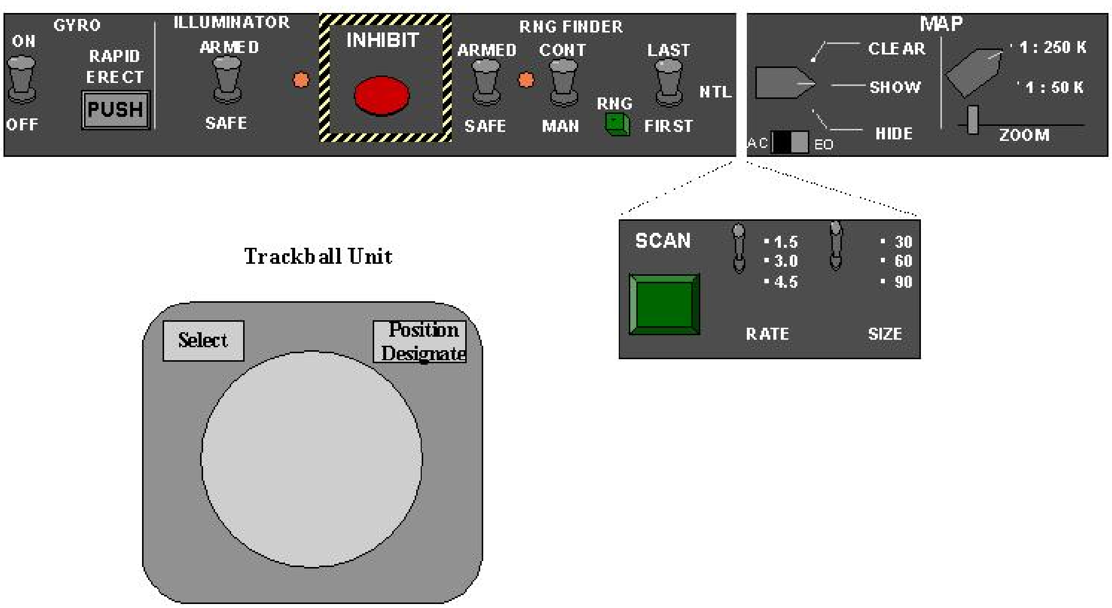

Figure 7. Bezel control panel and trackball proposed for the ELVISS OMI

ELVISS rapid prototype

The ALBEDOS rapid prototype, developed using VAPS, was expanded to include thermal IR image simulation and modified to incorporate the new ELVISS OMI concepts. The VAPS prototype provided high fidelity images of the display, and sufficient functionality to evaluate an operator's ability to control the sensors.

VAPS is a human factors tool running on a graphics workstation which permits a designer to visually and logically prototype control and display systems. The prototype created is essentially a functional equivalent of a control and display system and can be manipulated interactively, dynamically, and in real time. On screen "controls" (that simulate real controls) can be manipulated using a cursor, keyboard or touch screen. Hardware interfacing problems that may delay early prototype evaluation are eliminated and it is easy to make changes to the interface. Where required, alternate controls such as wheels, pedals, and joysticks can be directly linked to the virtual prototype to provide a richer emulation of the system interface.

The rapid prototype development for ELVISS implemented the design concepts shown in Figures 4 - 7 in an interactive environment suitable for the conduct of structured evaluations of ELVISS task sequences. It included sufficient functionality to demonstrate the display formats and control concepts. In situations where different functions behave in the same way, only one of the functions was implemented to reduce the time and effort required to accomplish the rapid prototype objectives.

A large part of the operator interaction with ELVISS is in effectively manipulating the sensors. The control aspects of the ELVISS OMI are therefore important in achieving a satisfactory interface. Unlike many rapid prototypes which concentrate primarily on display formats, it was essential that the ELVISS rapid prototype included realistic controls. Thus, hardware controls were used for the hand controller and a control box was built to represent the sensor control panel. It was also necessary to develop a realistic simulated visual environment in which the operator could exercise the controls. The prototype used a computer-generated environment in which the ELVISS-equipped aircraft flew a predetermined search pattern. This visual environment was accurately mapped in order that the moving map display presented to the operator matched the scene viewed through the ELVISS camera (Figure 4 shows the screen from the rapid prototype). This was accomplished by using a terrain database that was presented at high resolution in the sensor windows and at low resolution in the moving map window. Later, a topographical map of the area was shown in the moving map display rather than the terrain database. These features permitted evaluation of the situational awareness aspects of the operator interface.

The rapid prototype was used to evaluate the ELVISS design concepts with SAR personnel. As with the ALBEDOS review, the operators adapted to the controls very rapidly and felt that they could use the system with a minimum of experience. However, the final report [8] reiterated the requirement for automation and preset defaults if the system was to be used successfully by SAR specialists.

In addition, data capture capabilities were incorporated into the rapid prototype. This made it possible to use the system to collect objective performance measures. This capability has been used and enhanced since the completion of this project to evaluate several interface parameters [9 - 11].

Hardware prototype of ELVISS interface

The final step in the development of ELVISS was to produce a hardware prototype that could be used to evaluate the total system in flight trials. A major component of that hardware prototype was the operator workstation, which implemented the OMI design concepts. DRDC Valcartier developed a workstation for ELVISS based on the OMI design concepts instantiated in the rapid prototype. CMC was contracted to transfer the software from the VAPS-based rapid prototype into the DRDC console and to integrate the OMI with the ELVISS sensor suite [12]. Figures 8 and 9 show the display and console for the hardware prototype and Figure 10 shows the actual workstation along with the hardware to control the sensors, the 16- and 24-inch platforms, and provide all related functionality.

Figure 8. Display of the interface of the ELVISS hardware prototype.

There are some small differences between the original display as implemented in the rapid prototype (Figure 4) and the display in the hardware prototype (Figure 10). The changes were implemented because the hardware prototype used a 1024 by 1280 pixel Liquid Crystal Display (LCD). The OMI in the rapid prototype was based on the use of a 768 by 1024 pixel LCD.

Figure 9. ELVISS console. This is the intended design. Prior to the trials, the sliders were replaced with rocker switches because of an incompatibility with the AGTV.

Ideally, the hardware prototype would have allowed the evaluation of all or most of the design concepts recommended in the HEDAD-O [8], but technical, time, and cost constraints limited the functionality that could be implemented. One of the major limitations was the significant lag in the response of the 16- and 24-inch sensor platforms when commanded to modify their position. The lag made the task of searching an area and tracking a target extremely difficult. The lag occurred because the command signal from the hand controller went through the workstation before reaching the platforms. The planned solution is to design the system with a direct drive from the hand controller to the platform. A second major problem was a continuous misalignment between the two sensors. This was due to the use of different mechanisms for stabilization. The 24-inch platform uses a pendulum principle (the sensor is on a floating table within the ball) and the 16-inch is strictly a gimbal. When the aircraft was rolling, yawing or pitching, the 24-inch platform kept its floating table (and the AGTV) perfectly horizontal. Thus, the Inertial Measurement Unit (IMU) in the 24-inch platform did not sense any angular acceleration (or very little) and did not pass on any instructions to the 16-inch platform to correct its pointing direction and the thermal imager in the 16-inch platform followed the angular change of the aircraft. As a result of the misalignment, the operator could not use the thermal imager to maintain context while zooming in with the

AGTV for identification. Another consequence of this misalignment was a large error in target position when designating a target because the laser rangefinder was in the 16-inch platform and not in the 24-inch platform with the AGTV/IMU. Finally, the automatic tracker did not track a target for more than a few seconds. Coupled with the above limitations, this made it difficult for operators to maintain contact even when they detected a target. A detailed list of the limitations and the reasons for them are documented in CMC's report on the development of the hardware prototype [12].

Figure 10. Hardware installed inside NRC's Bell 412 helicopter

Evaluation of the hardware prototype

DRDC carried out an evaluation of the hardware prototype in collaboration with the Flight Research Laboratory (FRL) of the National Research Council of Canada (NRC) in Ottawa. The two stabilized platforms were mounted on NRC's Bell 412 research helicopter as shown in Figure 3. The associated instrumentation, including the interface, was installed on two certified racks (Figure 10) in the back of the helicopter. The intended purpose of the evaluation was to test the technical capability of ELVISS and the usefulness of the system as

implemented in the hardware prototype. Unfortunately, because of limitations with the hardware prototype, it was not reasonable to conduct a human factors evaluation of the OMI. A technical evaluation was carried out. It included four flights, three over the Connaught Range (land scenario) and one over the Ottawa River (water scenario). During these flights, the system was operated by personnel from DRDC Valcartier and the Directorate of Air Requirements (DAR). The performance of these operators was observed and their impressions of the system were collected after the flights. As well, the content of the display and communications during the flight were recorded and used to supplement observations.

The land scenario involved flying over the Connaught Range (Ottawa) in search of (1) a large canvas (45.7 by 22.9 cm), with white letters of different sizes, on the ground, (2) a downed aircraft with registration markings, letters (30.5 cm black) on one of the wings (white), and (3) a man with and without a life vest with retroreflective tape standing near the aircraft. The water scenario involved detection of a man in the Ottawa River (in a wet suit, with and without retroreflective tape) and in a liferaft. Both scenarios were carried out at altitudes of 150 and 300 m. In addition, targets of opportunity were tracked.

During the land scenario, operators were able to find and reacquire the targets listed above, but in the water scenario, it was difficult to find the man in the water. On the few occasions when the target was detected, it was very difficult to keep the target on the screen. The problems during the water scenario were attributed to the lag between moving the hand controller and the platform moving and the lack of synchronized images.

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Review of ELVISS OMI design concepts

As discussed above, the OMI for ELVISS was developed as a result of perceived limitations in the original OMI for ALBEDOS to meet the needs of the SAR specialist and was based on an analysis of the tasks required to operate ELVISS in a SAR helicopter environment. The design was implemented in the ELVISS rapid prototype and evaluated [8]. Since that time, the design has evolved because of recommendations following evaluation of the rapid prototype, hardware changes, and technical limitations. This section summarizes the current state of the OMI as implemented in the hardware prototype including the rationale for the design decisions, an assessment of the suitability of the current implementation, recommendations for improvements, and suggestions for further research and development. The summary is organized by the tasks the SAR operator needs to carry out. Initially, tasks associated with the direct operation of ELVISS are reviewed to provide the reader with an understanding of the system. This approach results in some duplication. However, we feel that duplication is essential to understand the strengths and limitations of ELVISS in the SAR operator's conduct of a mission.

Overall design philosophy

The overall design philosophy was to produce an interface that allowed operators to focus on the primary tasks of search, detection, and identification and provided them with the necessary information to search effectively and efficiently with ELVISS. While carrying out primary tasks, operators should not have to look away from the sensor images to handle controls or to find out the status of the sensors or other functions. Thus, critical controls that were used in parallel with steering the sensors were located on the hand controller (Figures 5 and 9). Secondary functions that were likely to be carried out in parallel with the steering task were located on a panel easily accessed by the left hand (Figures 6 and 9). Controls associated with a given function were located together and were discriminable by relative spatial location and shape. Critical feedback about the sensors (e.g., FOV of the laser illuminator) was located on the screen near the windows containing the sensor images. To support effective search, the display provided information about the sensors' direction relative to the aircraft (horizontal and vertical angle) and the world (location on a map).

Steering control tasks

The two sensors that make up ELVISS are mounted in separate stabilized platforms that can be rotated 360 degrees in azimuth and 180 degrees in elevation[3]. However, the platform containing the thermal imager (the 16-inch platform) is slaved to the 24-platform with the AGTV. Thus, it is only necessary to control the direction that the AGTV is pointing. The steering control tasks involve manually adjusting or maintaining the sensors' direction, invoking an auto-tracker to follow a specific target or invoking the auto slew to direct the sensors to a specific location on a moving map. In addition, it is necessary to align the two

[3] Because both platforms were located on the left side of the helicopter for the ELVISS flight trial and not under the belly (location of choice for mounting airborne platforms), the helicopter occluded the scene on the right side of the aircraft, limiting the useful FOV.

platforms so that the sensors are looking at the same thing. However, that task will disappear when the sensors are mounted in the same platform.

Manual control of the 16- and 24-inch platforms is carried out using the hand controller on the right side of the console (Figure 9). Feedback is provided by means of the polar plot between the two sensor images, the aircraft icon on the moving map, and the elevation indicator bar to the right of the primary[4] window (Figure 8). The polar plot provides feedback on the azimuth direction relative to the nose of the aircraft while the bar shows the vertical angle of the sensors relative to the horizontal. The aircraft icon indicates aircraft location and direction, while the footprint tethered to the icon shows the sensors' direction relative to the aircraft and information about the scene visible in the image windows.

If an operator finds an object of interest to track, he or she can initiate an auto-tracker by moving the contact to the centre of the AGTV image and pushing the auto-track button on the hand controller. Pressing the button again turns off the auto-tracker. In addition, the operator can change the tracker's parameters via the on-screen menus to try to improve the tracking capability of the system. Alphanumeric feedback on the auto-tracker's status is located between the two sensor images.

A third method for changing both sensors' position is auto slew. When an operator presses the auto slew button on the hand controller, the sensors' move to the currently designated location on the moving map. An operator designates a location by using the trackball to move a cursor to that place on the moving map and pushing the right or position designate button on the trackball (Figure 7). A crosshair is deposited on the map at the selected location and remains there until a new location is designated.

Issues and recommendations

While operators were able to steer the sensor easily in the ALBEDOS flight trial, they had difficulty in locating an object on the ground and responding to directions from other crew members. The polar plot, elevation indicator, and moving map were implemented to help the operator. In the ELVISS flight trial, operators were able to respond to suggestions about the location of targets based on their position relative to the aircraft. Unfortunately, the aircraft icon did not show the direction the sensors were pointing or their exact location. Thus, it was not possible to evaluate the usefulness of the aircraft icon for supporting the task of directing the sensors to a specific location.

In the design concept for ALBEDOS, the polar plot included range rings, providing an integrated picture of the sensor's direction and distance relative to the aircraft for ranges within about two nautical miles. With the addition of the second sensor image, there was not enough space for the range rings. In its place, an alphanumeric display (to the right of the polar plot) shows the range in nautical miles from the aircraft to the scene shown on the display. The alphanumeric display is useful for communicating range to other members of the crew, but it does not provide an integrated picture of direction and distance of a target relative to the aircraft. The tethered footprint on the moving map provides a rough indication, but the length of the tether varies as a function of the resolution of the map. Thus, the visual pattern is not

[4] The primary window is selected by pushing the AGTV or Forward Looking Infrared (FLIR) buttons in the "primary window" box in the sensor control panel (Figures 6 and 9).

consistent and additional mental operations are required to compute the scene distance relative to the aircraft. A display concept that provides an integrated picture of direction and range should be investigated.

The design for ALBEDOS recommended the use of a rigid handgrip with a proportional displacement thumb controller to control the movement of the sensors. Based on a subjective evaluation of different controls [6], it was felt that this type of controller provided the best combination of coarse and fine control and comfort as well as good hand support in a high vibration environment. However, in an empirical evaluation [9], carried out as part of the ELVISS design review, participants detected more targets and were able to track a target more consistently using a displacement hand controller than they were with the thumb controller. Since this evaluation took place using the rapid prototype in an environment without vibration, the results may not apply to the helicopter environment. The hardware prototype incorporated a displacement hand controller. One of the ELVISS field trial operators indicated that he pushed at least one of the function buttons on the hand controller with his left hand. This suggests either that there is a limit to the number of buttons that can be accessed or that there was a problem with pushing that button and keeping the image stable. Some operators found it difficult to grip the controller so that they could reach all the buttons while keeping their forearm horizontal. Unfortunately, the ergonomics of the workstation set-up in the helicopter was poor. The height of the controller and a low seat height relative to the console caused arm fatigue for all operators [12]. These ergonomic limitations may have contributed to problems using the controller's buttons. Guidance on the selection of a suitable hand-controller can be found in MIL-STD-1472F [4]. For aiming sensors in a vibration environment, it recommends a displacement thumb controller or a displacement hand controller plus good arm support.

In the ALBEDOS field trial, the operators found it fatiguing to manually track a target, especially when using a narrow FOV. For that reason, an auto-tracker was included in ELVISS. In the hardware prototype, the tracker could only be used with the AGTV image due to cost constraints. However, in the rapid prototype it could be used with the image from either sensor and it would seem preferable to implement that capability in the future. For example, if an operator detected something with the thermal imager, it would be helpful if the auto-tracker followed that object while the operator tried to detect the same object in the AGTV.

In the design for ELVISS, pushing the auto-slew button was supposed to move the sensors to the position of the crosshair on the moving map or to the aircraft heading at an angle 15 degrees below the aircraft's nose. The latter should happen when a position had not been designated on the moving map, but it is not clear when that could happen. According to the design documentation [8], the position marked by the crosshair remained selected (the position to which the sensors would slew) until a new location was designated. Thus, it appears that slewing to the aircraft nose is not possible without a design modification.

Another problem with the auto-slew function was that operators found it difficult to accurately position the crosshairs on the moving map in the high vibration helicopter environment - reducing the auto-slew's accuracy. With a low-resolution map, the accuracy of the auto-slew is likely to be further degraded. Thus, the auto-slew's value may be limited to allowing the operator to move the system quickly from one area to another. Despite its limitations, most operators favoured the capability to rapidly slew the cameras from one direction to another [3].

Even with the automation functioning properly, the steering control task will be carried out manually during the search phase of the task. Videotapes from the ALBEDOS field trial showed that operators moved the camera a relatively small amount while searching. In that trial, the feedback on the sensor's direction, although not intuitive, was located right on the overlay (see Figure 1). Studies of eye movement in unaided air-to-ground visual search [13] similarly show that the scan patterns of searchers are smaller and less systematic than searchers' claim. For these reasons, the rapid prototype allowed the operator to invoke an automated scan pattern over a defined angle and at a defined rate. With an automatic scan function, the operator no longer has to be concerned with maintaining a suitable scan pattern in an environment with minimal cues and can concentrate on monitoring and optimizing the image.

Although an automatic scan function was not implemented in the hardware prototype, most operators that have used ALBEDOS or ELVISS in flight trials thought automatic scanning would significantly reduce the workload associated with steering the sensors. However, an independent critique of the ALBEDOS design [14] suggested that an automated scan function would reduce the interaction of the operator with the system and might contribute to the vigilance decrement associated with all search tasks with low signal rates. This problem has to be traded off against the ability of the operator to carry out a systematic manual search under conditions of minimal context. Moreover, operators find the requirement to constantly adjust the hand controller fatiguing which can also lead to a vigilance decrement. To date, the feasibility of an automated scan function has not been investigated. Moreover, most of the laboratory studies in support of ELVISS have either been of short duration or have not involved a significant search component. Thus, we do not have a good understanding of manual search performance with ELVISS. It would be useful to compare manual and automated scanning when searching in degraded environmental conditions over an extended period of time.

AGTV Illuminator control tasks

The AGTV illuminator is composed of a pulsed laser source to illuminate the terrain viewed through the low-light level camera and the associated electronics to synchronize the operation of the laser with the AGTV camera. The operator can arm and disarm the laser, switch it between active and passive mode, select the desired beam width or divergence (2 or 10 degrees), and adjust the beam's power level and pulse width. The beam divergence determines the scene area illuminated by the laser beam in active mode. In addition, the operator can adjust the gate range and width. The gate range determines the time between when the laser pulse is emitted and the camera lens is opened and the gate width is the length of time the lens stays open. From the operator's perspective, the gate range is the distance at which the camera picks up the laser light reflected off objects or surfaces and the gate width is the distance in depth over which the reflected light is picked up.

Arming the laser provides power to the laser illuminator. It is a precursor to activating the laser and is usually carried out during startup. The critical concern here is that the laser beam not be armed accidently, especially when the laser is in active mode. Arming is controlled by a two-position Laser Armed/Safe switch (on the bezel control panel, Figures 7 and 9). The "Armed" selection is inhibited by use of a spring loaded switch which returns to the "Safe" position when released unless the passive laser mode has been selected. When "Armed", the status

light beside the switch is illuminated to provide visual feedback in addition to the switch position.

Switching the laser illuminator between active mode and passive mode and changing the beam divergence are actions that will be carried out during a search. Thus, the controls must be readily available to operators while steering the sensors and monitoring the image on the display. Both the laser illuminator mode and beam divergence are changed by toggle switches located at the top of the hand controller (the switches on either side of the red button in Figure 9). Alphanumeric feedback on the laser illuminator's status is provided at the top of the AGTV image.

The design called for the laser beam's power level and pulse width to be changed using the on-screen menus because previous technical evaluations indicated that they would be adjusted infrequently. However during the ground tests of the hardware prototype, it proved necessary to adjust the pulse width whenever the beam divergence was changed. As a result, the pulse width control was moved to the sensor control panel (the switch labelled gain in Figures 6 and 9) and feedback on the current pulse width was added to the alphanumeric overlay at the top of the AGTV image.

The gate range and gate width are both controlled by sliders[5]. Moving the sliders away from the operator, or up, increases the range and width. The up/down orientation of the slider corresponds to the near/far relationship relative to the operator, with minimum range being near/down and maximum range being far/up. The sliders require a slight depression by the operator to release them. This ensures that they do not creep due to aircraft vibration or that the operator does not move them accidentally. The bar on the left side of the AGTV image provides feedback on the gate range and width (Figures 4 and 8). The position of the black band in the bar indicates the relative gate range and the width of the black band the relative gate width. Alphanumeric information on the gate width is provided at the top of the AGTV image.

On clear nights, it is not necessary to gate the laser beam. Thus, above the sliders is a two-state, momentary action switch that affects the action of the sliders. When in continuous mode, there is no gating of the reflected laser light and the sliders have no effect. When in gated mode, the switch and the two red indicator lights at the top of the sliders are illuminated.

Issues and recommendations

The recommended design for activating the laser illuminator and changing the divergence was a single three-position switch that went from passive to 10 degrees to 2 degrees (switch labelled "LASER FOV" in Figure 5). A single switch reduces memory load and requires less movement of the thumb while operating the hand controller. With two switches, the operator is less likely to inadvertently switch into passive mode. The critical concern is being able to carry out these functions without looking away from the screen. Both the single and dual switch configurations allow this to happen. During the evaluation of the ELVISS rapid prototype [8],

[5] In the final version of the hardware prototype, the sliders were replaced by rocker switches because of an incompatibility between the sliders and the outputs from the AGTV system. However, in a fully operational prototype, sliders would be implemented. Thus, that is the design option referred to here and shown in Figure 9.

SAR specialists found that the three position switch could be adjusted without introducing inadvertent inputs into the camera pan and tilt controls. However, they used the hand controller in a vibration free environment.

The requirement to adjust the laser's pulse width when the beam divergence is changed negates the advantage of putting the beam divergence control on the hand controller and makes the adjustment of beam divergence a complex task. However, an optimum pulse width can likely be associated with each beam divergence and a change in pulse width linked directly to a change in beam divergence. This should be investigated and implemented if possible. Otherwise, the design of the laser illuminator's controls should be revisited with the goal of simplifying the process for changing beam divergence and pulse width.

Operators will likely manipulate the gate range and width while monitoring the sensor image. Thus, they should not have to look at the console when operating these controls. Using lights on the console to indicate the status of the range-gate function is inconsistent with this design goal. The preferred solution is a two position, toggle switch for the continuous/gated options, as recommended in a critique of the ALBEDOS design [14], and removing the black band from the gate range bar when the system is in continuous mode. As well, most of the operators found it difficult to see the range bar. One suggestion was to outline it in black[6].

In the ALBEDOS field trial, operators were rarely able to optimize the range-gating while searching. This was due in part to using discrete (toggle switches) instead of continuous controls. The sliders simplify the task of controlling the two parameters. They do not help the operator choose the best range and width especially under poor weather conditions. Unfortunately, both field trials were conducted in relatively clear conditions reducing the need for a specific range and width. Thus, we do not know how difficult it will be for operators to manually select an optimal gate range and width under poor weather conditions. Given the nature of the search task in the SAR environment, one can anticipate that it would be almost impossible to determine the optimum range and width in a timely fashion based on visual cues in the sensor images. Moreover, the ideal range could change frequently especially in poor weather where a narrow gate width would be used. Thus, the operator could be faced with constantly adjusting the range while trying to maintain a systematic scan pattern. During the ELVISS field trial, the operators tended to focus on the image and ignored the other system functions. This suggests that the current system will not be set-up optimally during poor weather conditions.

For the above reasons, the ELVISS rapid prototype included an automatic mode for the range that was activated by a two-position, toggle switch located beside the range slider (labelled "RANGE" in Figure 6). In automatic mode, the gate range would be calculated using the laser rangefinder (or the georeference system). In manual mode, the range was determined solely by the position of the gate range slider. The slider control was either disabled when the range switch was set for automatic operation or else limited to making fine adjustments to the automatic range.

It was not technically feasible to implement the automated range mode in the ELVISS hardware prototype. However, the range can be set manually using the information from the laser rangefinder. Given that the ideal range can change rapidly, due to changes in aircraft

[6] See also the section on image quality.

altitude, terrain height, and sensor direction, the existing solution is probably of limited utility. Thus, the implementation of an automated range mode is a high priority.

A recommendation in the original ALBEDOS report [3] was to provide the operator with an indication of preferred gate width for different weather conditions. Operators will probably learn the best gate width to use for different weather conditions with experience, but this information could be acquired more easily through systematic analysis of the relationship between gate width and visibility of defined targets ([15] provides an example of how this might be done). The results could be incorporated into the OMI by providing a multi-position switch for the gate width or labelling the slider. The switch or slider could be supplemented with an intelligent agent that requested information on the weather conditions in the search area and then recommended a suitable gate width.

Sensors and lens control tasks

The sensors pick up visible and IR radiation, emitted by and reflected off the terrain, and transform it for presentation to the operators. Several different sensor parameters can be modified to optimize the images for different purposes (e.g., search and identification). The operator can set the FOV, focus, level, and gain of the low-light level TV camera and the thermal imager plus the polarity of the thermal image. The thermal imager's FOV can be shifted between wide and narrow (10 and 2 degrees) by pushing the button on the lower left side of the console (Figure 9) marked "FOV". The console button is illuminated for a narrow FOV and feedback is also provided at the bottom of the IR sensor window with the text "WIDE" or "NAR". The AGTV's FOV can be adjusted continuously from wide angle to telephoto using the thumb wheel control labelled "ZOOM" in the upper left side of the console (Figure 9). A box in the centre of the sensor window that expands as the user zooms in, by pushing the thumb wheel control forward, provides feedback. The zoom control adjusts the lens' focal length from 16 to 400 mm or from 32 to 800 mm. The "ext" button on the upper left corner of the console switches between the two ranges (i.e., it puts in place or removes a 2X extender optical component in the zoom lens). If the "ext" button is illuminated, the 32 to 800 mm focal length is enabled.

For both sensors, the focus is adjusted by means of rotary control potentiometers on the left side of the console. Usually, it is only necessary to adjust the AGTV's focus when zoomed in; otherwise, it can be left at infinity. Since the operator is likely to adjust the focus after zooming in, the zoom and focus controls are close together allowing the operator to shift from one to the other without looking away from the screen.

The brightness and contrast of the two images can be changed by adjusting the level and gain of each sensor system. In addition, the AGTV's zoom lens has an adjustable iris. Only an experienced operator can optimize the iris, level, and gain and the process can be time consuming. There is no time to make these adjustments while searching. Thus, except for the iris, these adjustments are handled automatically by the AGTV and thermal sensors. It is usually not necessary to adjust the iris since it is normally maintained at fully open during night operations. The level and gain can be adjusted manually through the menus. In addition, the polarity of the thermal image can be changed from black hot to white hot by pushing the button labelled "POL" (bottom left of console in Figure 9) that is illuminated when the polarity

is set for black hot. Feedback on the current values of all these functions is overlaid on the appropriate sensor image.

Issues and recommendations

The sensor control tasks will largely be carried out while the operator is steering the sensors. Thus, a critical concern was to design the controls and feedback so that the operator would not have to look at the console. In the rapid prototype for ELVISS, the thumbwheel control for the AGTV's focus was smaller than the control for the zoom (Figure 6). In the hardware prototype, the thumbwheels are the same size and the operator must position his fingers on both controls to determine which is which before operating one of them. The size cue makes this less necessary. In addition, as stated earlier, the use of toggle switches instead of the buttons used in the hardware prototype was recommended for functions such as changing the FOV and polarity of the thermal imager [14]. Implementation of both of these recommendations on the hardware prototype could further reduce the need to look at the sensor panel while searching.

During the ELVISS field trial, operators found it difficult to steer the sensors and adjust the zoom at the same time. This may have been due to the lag in the system described earlier. However, it is difficult to keep an object in the centre of the screen as one zooms in, even in the rapid prototype. A working auto-tracker should overcome this problem. Operators also found it very time-consuming to zoom out when they wanted to resume a search and recommended a rapid zoom function. A zoom-out function could be useful, but it may be difficult to keep an object on the screen with a rapid zoom-in. However, if the auto-tracker could track the object of interest on the thermal display, this would be less of an issue. FOV research conducted at DRDC Toronto [10] supports the request for a rapid zoom. In those studies, people tended to use the extremes of a continuous zoom capability for the AGTV when it was coupled with a discrete zoom capability for the thermal sensor. During a search, they used as wide a FOV as possible and when they detected something, they would immediately zoom in as much as possible.

In the ELVISS field trial, operators did not use the 2X extender (32 to 800 mm) because they found that light levels were reduced and it was more difficult to keep track of the target and keep the image focused. It is unlikely that the extender will be of much advantage without an auto-tracker. This finding along with the request for a rapid zoom should be taken into account if a replacement for the optical system for the AGTV is under consideration.

In both field trials, the primary cue for FOV was the image itself. In fact, one operator found the box, that provided feedback on the zoom on the ELVISS OMI, annoying. However, in extended searches over unfamiliar terrain, a secondary FOV cue could be helpful.

Most operators in the ALBEDOS field trial favoured an auto focus. An automatic focus control was recommended in the proposed design for ELVISS, but was not implemented in the hardware prototype for technical reasons. During the ELVISS field trial, the operators reiterated the need for an auto focus capability for both sensors. Although the focus is usually adjusted only when the sensor is zoomed in, this is a workload intensive period. Also, fine adjustments are often required, which can be difficult while using the hand controller. On the other hand, operators might find it even less acceptable if the auto-focus were continuously

adjusting the image to compensate for aircraft movement. Thus, care will have to be taken in implementing an auto-focus function.

Laser rangefinder control tasks

The laser rangefinder (LRF) provides the operator and the georeference system with an estimate of the distance from the aircraft to the ground at the centre of the thermal image. The operator can switch between armed and safe, put the LRF in continuous (pulse train) or manual (single) mode, trigger the LRF (directly or via the target designate function), and set the LRF to use the first or last pulse to determine the range. As well, the operator must align the LRF with the thermal sensor to ensure that they are looking at the same point when the LRF is triggered. This is done using the LRF “boresighting” menu.

Toggle switches, located on the bezel control panel (Figures 7 and 9), are used to arm the LRF and switch between manual and continuous mode and the momentary switch labelled “rng” triggers the LRF (Figure 7). The red light between the switches is illuminated when the LRF is armed. Pushing the target designate button on the hand controller (red button in Figure 9) triggers a single pulse independent of the mode. The range is shown in alphanumeric format on the right between the two sensor images. Pulse selection is done using the on-screen menus.

Issues and recommendations

The ELVISS design recommendations called for the LRF to pulse continuously in the continuous mode. It was anticipated that the LRF would operate continuously under most conditions making accurate range information readily available. As such, there would be little requirement to trigger the LRF using the range control on the bezel control panel. However, the LRF in the ELVISS hardware prototype cannot be pulsed continuously without damaging the crystal. Thus, it was decided that, in the continuous mode, the LRF would pulse at 1 Hz for 30 seconds when triggered. A better solution would be a continuous mode that took account of the limitations of the LRF by pulsing at a slow rate or in bursts with a suitable separation.

Target-designate tasks

The target-designate function allows the operator to mark a ‘contact of interest’ on the moving map and capture the primary sensor image at that point in time. As well, it calculates the latitude and longitude of the location at the centre of the captured image and displays it above the contact menu list. The operator marks a location by pushing the target designate button on the hand controller. A numbered marker on the moving map indicates the contact location. To view the image later, the operator uses the trackball to position the cursor over the same number on the contact menu list (beside the image capture/menu area in Figure 8) and presses the trackball’s left or “select” button.

Issues and recommendations

The ELVISS HEDAD-O [8] recommended that latitude and longitude information be transmitted directly to the navigation system and not be presented to the SAR operator. It was argued that the operator had no requirement for that information and direct transmission would

avoid the error prone use of verbal transmission. It was not possible to implement electronic transmission, but the latitude and longitude are displayed above the contact menu list. During the ELVISS field trial, the operators thought that latitude and longitude could be useful. For example, they could compare the location of a current contact with information from Electronic Location Transmission (ELT) reports or contacts from previous flights. Thus, they favoured displaying the latitude and longitude information as well as direct transmission to the navigation system.

Designers anticipated that the operator would use the image capture facility to compare a captured image scene with the current image. Without auto-tracking, the operator must control two analogue devices simultaneously (the hand controller to maintain the current image and the trackball to locate the old image) to view a captured image. In this situation, the operator should also be able to use a discrete control to cycle through the contact list. As well, the system should always display the image closest to the current sensor position. When it is reasonable to use the trackball, it would be more efficient to select the image using the contact marker on the map than finding the contact number on the map and then finding that number on the contact list. However, direct selection might conflict with the auto-slew function.

Moving map tasks

The moving map and associated overlays were added to the interface to provide overall situation awareness to the operator. Two different map resolutions are available. Moving map tasks include selecting a map resolution and zooming in and out at each resolution. Controls for these functions are on the right side of the bezel control panel (Figures 7 and 9). The operator changes the resolution using the knob at the far right of the panel and zooms in and out using the slider below the knob. Since these are digital images, zooming does not change the level of detail.

Issues and recommendations

The ALBEDOS and ELVISS rapid prototypes used an artificial terrain database to simulate the terrain being viewed by the sensors. Since, there was no corresponding map, a lower resolution, greyscale view of the terrain simulated the moving map. As a result, some unexpected problems arose with the digital map in the ELVISS hardware prototype. The digital map was colour coded which could be distracting [14] and the visibility of alphanumeric overlays on the map, including the aircraft icon, was poor. Two possible methods for making the map less distracting are to use desaturated colours and to allow the operator to adjust the brightness of the moving map. The first method, desaturated colours, was implemented on the digital map in the hardware prototype. One operator commented that he like the “soft colours”. The visibility of the overlays could be improved by putting a plain background behind the map’s alphanumerics, as used with the alphanumeric overlays on the sensor images, and drawing a thicker aircraft.

A second issue with the moving map was determining the size of the sensor’s footprint on the moving map. In the rapid prototype, the footprint indicated the area covered by the primary sensor and its size and shape changed as a function of the sensor’s range and FOV. With the digital maps employed in the hardware prototype, the map’s resolution was too low to show the actual area covered by the primary sensor. Thus, the footprint shown on the hardware

prototype (Figure 8) only indicates the general location of the area covered by the primary sensor.

In the rapid prototype, a history of the sensor's path was overlaid on the moving map as a crosshatched cyan pattern (see Figure 4). The history could help an operator re-establish a search after checking a possible contact and provide feedback on how systematically the terrain was being searched. The operator could display, hide or clear the history using the three position switch on the bezel control panel (Figure 7). The history overlay was not implemented in the hardware prototype, but as with the sensor's footprint, the map's low resolution meant that the history would not accurately cover the terrain searched. At best, it would indicate the location of the terrain that had been searched. Recently, the ELVISS rapid prototype has been upgraded to use realistic digital maps. Thus, the usefulness of the history and the best method for presenting the history (see [14] for possible alternative methods) should be investigated.

In the rapid prototype, the moving map could be oriented north-up, aircraft-up, or sensor-up. The three modes were provided for evaluation purposes only. The intent was to implement only one or two modes at the most. The evaluation of the ALBEDOS prototype indicated that the operators did not like the sensor-up mode, but there was no consistent preference for either of the other two. The two remaining modes were evaluated during the empirical investigation of the ELVISS prototype [9], and there was no significant difference in search performance between the two modes. However, the potential effect of aircraft movement was not simulated in the aircraft-up mode. In a more realistic environment, the continuous variation in the flight path of the aircraft could negatively affect performance with an aircraft-up moving map unless suitable dampening factors are included.

Menu control tasks

An on-screen menu area was included as part of the ELVISS rapid prototype to adjust seldom used parameters especially those that are changed at the start of a run or by expert users. The use of menus reduced the number of controls, making it easier to find critical controls without looking down (a problem during the ALBEDOS field trial). Menu control tasks include displaying the menu, navigating through the menu, selecting a menu item and editing a menu. Menus are displayed in the lower right corner of the screen in the same area as the screen capture images (compare Figures 6 and 8), and the controls are located in the corresponding lower right corner of the sensor control panel (Figures 6 and 9). Pushing the button labelled menus brings up the top-level menu. The up/down arrow keys allow the operator to navigate within a menu. A small arrowhead icon beside a menu item indicates the existence of a submenu. Highlighting a menu item and hitting the right arrow key will bring up the submenu when an arrowhead is present. Otherwise, it will make the item editable. The +/- keys are used to step through menu item options (e.g., for thermal mode: auto or man), or modify numeric values (e.g., gain of AGTV).

Issues and recommendations

Discrete controls were recommended for accessing the menu given the difficulty of simultaneously operating the trackball with the left hand and the hand controller with the right. However, the sole use of arrow keys for interacting with a menu is not common. In most applications, menus items are accessed using a cursor controlled by an analogue device such as

a mouse or trackball and parameter values are either typed in or selected from a preformatted list. If there is a limited need to access the menus, providing only the arrow keys is reasonable. However, frequent access may be necessary during set-up and if tasks such as boresighting are carried out via the menus. Thus, it would seem reasonable to allow menu access using the trackball controlled cursor. If both methods were available, the operator could use the most efficient method.

The development and evaluation of the menu area was relatively limited. Evaluation focused on the suitability of menus for modifying infrequently changed parameters and the method for accessing the menu. Prototype menus were developed, but they were no longer relevant for the hardware prototype. The menu design should be reviewed once the hardware is well defined because the current design assumes a small number of shallow menus no more than two levels deep. If more extensive menus are necessary, an alternative interface should be investigated.

Start-up and shut-down tasks

Start-up tasks put the system into a useful state and shut-down tasks turn the system off safely. Some of these tasks will disappear and others will be added as the hardware prototype evolves into a working system. Thus, generic rather than specific tasks are described below. The operator completes these tasks through controls on the bezel control panel or the menus. The controls are used to turn system components on and off and the menus to configure sub-systems. Feedback for the controls is usually provided by switch position and for critical systems, such as the laser illuminator and rangefinder, by an indicator light. System status information is shown in the menus themselves and in a few cases in the overlays (e.g., iris setting) on the sensor images.

The hardware prototype operator is provided with a start-up and shut-down checklist to ensure actions are carried out in the correct order, critical switch settings are correct, and functional checks are carried out. First the operator must make certain that all sub-systems are in a safe state (e.g., lasers in safe mode or turned off). Next, the various components of the system are powered up. Finally, the system is configured for the search conditions and possibly the operator's preference.

Normally, each menu item would come up with a default value. At the moment, the best default value is not known. Thus, the hardware prototype software reads in a list of default values during start-up. This list can be edited offline prior to start-up, reducing the number of menu items that need to be accessed every time the system is turned on.

Issues and recommendations

During the ELVISS field trial, operators spent more time accessing the hardware prototype's menus than was anticipated when the ELVISS design concepts were developed. One reason was that operators had to access the menus to check the status of system parameters as well as change them. The design recommendations for ELVISS called for a status page that overlaid the sensor images when the status button in the menu area of the sensor control panel was activated (Figure 6). However, this functionality was not incorporated. A status page would

allow a more efficient review of the system parameters and should reduce the requirement to access the menus.

In the review of the ALBEDOS design, it was recommended that the ability to change the system set-up be kept to a minimum [14]. The rationale was that allowing SAR operators to configure the system could waste time during system turnover and result in a non-optimum selection of parameters. On the other hand, it is unlikely that the default parameters will be suitable for all stages of a search because of variations in the weather or the operator's goals. An alternative solution would be to provide a decision support system that configured the system based on projected environmental conditions and search goals. The intelligent agent proposed earlier for the gate width could be part of such a system. This type of aid would also alert an operator to the kinds of factors that might impact system performance.

Search task

Search tasks include systematically scanning the terrain for targets, responding to other crew members' suggestions about contacts of interest, and monitoring weather conditions. Search tasks specific to ELVISS include adjusting the AGTV's zoom, gate range, and gate width, changing the FOV of both sensors between 2 and 10 degrees to improve the probability of detection, and monitoring and adjusting the moving map to better direct the search.

The operator scans each sensor image while using the hand controller to steer the sensors over the terrain below. If another crew member points out a possible object of interest using a clock position and slant angle, the operator can use the polar plot and the elevation indicator bar to steer the sensors to the recommended location. The operator can use the moving map to get a context for the images.

The controls to optimize each sensor image are located on the sensor control panel. An operator can manipulate them with the left hand while steering the sensors with the right hand. The AGTV controls are at the top and thermal imager controls at the bottom of the panel to facilitate locating them without looking down. Feedback is superimposed on the relevant image or on the control itself. If an operator is concerned that the range may not be correct, he/she can activate the laser rangefinder to get an accurate estimation which can then be used to adjust the gate range.

Issues and recommendations

During the ALBEDOS field trial, the SAR specialists were sceptical that the AGTV would be useful in an extended wide-area search because of the limited FOV. They thought it would be used primarily for identification and for searching small, well-defined areas [3]. Similar comments were made during the ELVISS field trial even with the improved interface and a second sensor. However, both sensors had the same FOV. In recent studies with the ELVISS rapid prototype, on the effect of FOV on probability of detection [10], best performance occurred with a thermal IR imager with a 20 to 40 degree FOV accompanied by an AGTV system with a narrow (.5 to 5 degree) FOV for identification. Target detection was significantly poorer with a 10 degree FOV. Thus, it is important that one of the sensors, probably the thermal imager, has a FOV of at least 20 degrees.

The moving map was seen as a way of extending the FOV in order to provide an operator with better situation awareness. In the ELVISS field trial, a small area was searched and the terrain was familiar to the operators. In addition, the weather was good and the pilot was able to provide points of reference to the operator. Thus, there was little reason to use the map. The sensor's footprint on the moving map might have helped the operators to more precisely position the sensors especially when searching near the shoreline, but its location was inaccurate because of the slow movement of the helicopter (the helicopter has to fly at a certain speed before the georeference system provides accurate data), the slow update rate (due to lack of computer processing power), the lag in the response of the platforms, and finally the lag between the two platforms. Thus, the operators were not able to use the sensor's footprint although they thought it had potential. A laboratory study looking at the utility of the moving map found that it was of less benefit than anticipated [11]. It helped marginally when the operators were unfamiliar with the terrain. However in that study, there was no specific link between the detection of targets and the information provided by the map (e.g., the aircraft probably went down in trees or along a shoreline). There is another reason why the map may not be used. The operators must shift their gaze away from the sensor images to use the map. This problem was recognized during the ELVISS field trial leading to the suggestion that the image should be overlaid on the map. While the technology for doing that exists, none of the applications to date have involved real-time search using multiple sensors[7]. More research is required using realistic digital maps and alternative technologies under a wide range of search conditions to understand how the map may and can be used.

During the development of the ELVISS OMI, a major emphasis was on supporting the operator under poor environmental conditions. Most of these design concepts have been discussed already. They include a moving map overlaid with a history of the scanned terrain, automatic control of the gate range, an annotated gate width control, and an automated scan capability. In addition, it was recommended that an automated detection algorithm be investigated. Automated detection is often of little value because of high false alarm rates. Operators spend more time handling false alarms than searching and end up turning off the automation. However, a high false alarm rate may not be a problem with ELVISS. The purpose of the ELVISS auto detect function is to compensate for the vigilance decrement associated with monitoring a display for a low probability event. The introduction of false targets has been shown to reduce the vigilance decrement in environments with low signal rates [16]. If the false alarm rate was manageable, an auto-detect function might be useful. On the down side, the introduction of automation has been shown to lead to poorer monitoring in some tasks [17]. Since the outcome may be task specific, it would be worthwhile investigating the impact of an auto-detect function on operator performance and vigilance in this type of search task. In the interim, the ELVISS HEDAD-O [8] recommended limiting continuous searching to 15 minutes at a time and sending the imagery back to a ground station for further analysis.

Searching systematically is probably the most difficult task carried out by a SAR specialist. They are trained in search techniques, but even in full daylight with a lot of context, it is difficult to maintain a search pattern that systematically covers the relevant terrain [13]. Working at night, in poor weather, with a limited FOV, it is even more difficult. In addition, with ELVISS, an operator must set the gate range and width accurately to detect an object. In order to define the potential role of ELVISS, it must be evaluated under poor ambient weather

[7] See www.idelix.com for examples of applications using this type of technology.

conditions, but it is unlikely that field trials would be permitted in such conditions. Thus, the capability to simulate poor weather conditions should be developed. Studies could then be conducted that compare performance simulating the condition in the field trial with performance under various simulated poor weather conditions. Such a study would hopefully lead to a better understanding of ELVISS' role in the SAR environment.

Detection task

The detection task involves finding a contact of interest in one of the images, providing information about its location, and if necessary, reacquiring the contact after the aircraft has repositioned itself. To get an accurate location, the contact must be centered in the primary sensor's image using the hand controller. The location information available from ELVISS is the azimuth or clock position relative to the aircraft nose from the polar plot and the distance to the contact from the range readout. Operators can get a more accurate range estimate by pushing the LRF range button on the bezel control panel. In addition, an operator can mark the contact location on the moving map and capture the image by pushing the target designate button on the hand controller. This function also triggers the LRF and displays the latitude and longitude of that scene. The operator can pass all this information to the navigator. Only the primary sensor image is captured and the number of images that can be stored is limited to six. If available, the operator could initiate the auto-tracker to keep the contact in view.

Issues and recommendations

The six image limit was based on the assumption that operators would use image capture infrequently because they could usually identify an object using the AGTV's zoom. They would use image capture when they were unable to identify a contact and wanted to retain an image for post flight debriefing. However in the ELVISS software and hardware prototypes, image-capture is combined with the target designate function. Operators are trained to use a liberal criterion for calling a possible contact. To avoid losing a contact, an operator would mark it. Thus, the number of designated contacts could be quite large, but most of them would be relevant for only a short time. Since the system automatically deletes the oldest contact, an operator would have to ensure that only irrelevant contacts were deleted. This task would probably not be a high priority, and the operator would likely have to do it when busy with a new contact.

If the image capture and target designate functions were separated, the requirement to manually delete images might disappear. Separate functions require an additional decision – 'am I likely to want an image of this?', and an additional action if the answer is yes. Moreover, during evaluations of the rapid prototypes and the field trials, most operators indicated that they wanted to be able to store more than six images. It is not clear if they made this recommendation because they wanted to mark many contacts or because they saw other uses for the image capture function. Based on supporting comments, it was probably the latter. Thus even if the two functions were separated, there would still be a requirement for more than six images.

If the number of stored images is increased substantially, operators could face a cluttered map. However, it still seems preferable to increase the number of images stored and keep the two

functions linked. In addition, some form of intelligent support to minimize clutter and maximize the visibility of potentially relevant contacts should be investigated.

Classification tasks

Classification involves determining if a contact is a target of interest. In order to classify the target, an operator would centre it in the primary sensor image, invoke the auto-tracker, zoom in, and then adjust the focus and possibly the gate range and width. If the target could not be clearly identified, an operator might capture the close-up image.

Issues and recommendations

The simultaneous control of the hand controller and zoom has proven challenging for operators. In both field trials, even experienced operators found it difficult to keep the image centred on the screen while zooming in and adjusting the focus. During the ELVISS field trial, one operator controlled sensor direction while a second controlled the zoom. In contrast, operators were able to zoom in relatively easily in the rapid prototype where an auto-tracker was available. Since the auto-tracker did not work in the hardware prototype, its efficacy could not be evaluated. Auto-tracking is widely used, but it is not clear if the applications are as challenging as tracking with ELVISS. Thus, it is important to determine what can be achieved with current technology, and if necessary, develop methods for optimizing auto-tracking in ELVISS.

Other issues

To this point the review has focused on the extent to which the system met the requirements developed in the function task analysis and overcame the limitations of the ALBEDOS interface. As frequently happens, planned improvements can introduce new and unforeseen problems.

Display contrast

One of the requirements for ELVISS is that it be as compact and portable as possible. For that reason, the hardware prototype uses a LCD monitor since it has a smaller footprint than a traditional Cathode Ray Tube (CRT) monitor. Because of software limitations, it was necessary to include Wescam’s ALBEDOS interface in the ELVISS hardware prototype during the field trial. This allowed a comparison between the LCD and CRT monitors. Most users found the images less visible on the LCD as compared to the CRT. In some cases, targets could be seen on the CRT and not on the LCD. Users also stated that they found it harder to focus the images on the LCD.

Without further analysis, it is difficult to determine if these problems are due to the use of LCD technology or to problems in transmitting the image. Most LCDs have a ‘higher’ black level than CRT displays; that is, the black is not as black. This difference is more apparent in a dark environment such as a helicopter at night. However, the moving map’s relatively high brightness should have made the black areas of the LCD appear black even in the helicopter. A more likely cause is poor mapping of the intensity of the image data onto the intensity of the

LCD. With Wescam's interface, the whole dynamic range of the CRT was used to display the AGTV image. The LCD presents a wide range of graphical and alphanumeric data including the moving map and the thermal image. Depending on how the intensities of these various data sources are mapped onto the intensity range of the LCD, the range of intensities used for the AGTV image may be significantly smaller. As well, the ELVISS application is overlaid on the operating system of the host computer which may distort the mapping of the AGTV output onto the LCD. One or all of the above factors may reduce the range of intensities used for displaying the AGTV image, which in turn will reduce image contrast. Another possibility is that there was some line loss in the transmission of the data from the AGTV to the LCD. This would result in poorer contrast and could also make the image appear slightly fuzzy. The latter would make the user think that the image was out of focus.

Whatever, the source of the problem, it is important that the system/display not reduce the target detection threshold for objects in either sensor image. The potential impact of the display on target detection can be assessed by putting a known signal through the system and measuring its output at the display surface.

Alphanumerics

Most of the operators found the size and contrast of the alphanumerics acceptable. They were easily visible, but not too bright. However, the field trial was of relatively short duration. During long searches, in a high vibration environment, larger alphanumerics may be preferred to compensate for vibration, fatigue and the low illumination level.

The operators did comment that they found it difficult to interpret some of the mnemonics and felt that they could be more intuitive. In some cases, the lack of intuitiveness arose from the dual nature of the prototype. Some of the feedback supported the technical evaluation and will disappear in a commercial system. However, in other cases, the complaint was justified. This kind of problem can be resolved through the use of focus groups to assess the intuitiveness of the terminology and icons used on the OMI.

Concept of operations

Some operators expressed concern about ELVISS' impact on the nature of the SAR specialist's job. They thought that ELVISS would make the search process more boring and result in less communication with the pilots. One way of addressing this concern is through focus groups with SAR specialists to look at concepts of operation for using multi-sensor surveillance systems. Focus groups were conducted during the initial stages of design development, but the lack of an actual system made it difficult for SAR specialists to understand the implications of introducing this type of technology.

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Recommendations

Although it was not possible to formally evaluate the ELVISS hardware prototype's OMI, evaluations of the rapid prototype plus comments from operators suggest that the design concepts developed for ELVISS represent a substantial improvement over the Wescam's ALBEDOS interface. The OMI meets the design goals of providing an interface that supports the operator's situational awareness and reduces the time required for tasks other than search, detection, and classification. Operator experience with ELVISS has also led to additional recommendations for improvements. These are categorized below according to their known potential to improve the system's usefulness for a SAR specialist. Some recommendations may not be technically feasible in the next generation system. However, the list provides guidance on areas where it is important to invest development dollars. The page(s) on which each recommendation is discussed is provided in brackets.

Existing design concepts

The main recommendation is that the design concepts implemented in the OMI for the hardware prototype be incorporated in the next generation of multi-sensor surveillance system incorporating an AGTV and thermal imager, especially if it is being developed for SAR operations.

Due to technical limitations and cost restraints, not all of the design recommendations in the ELVISS HEDAD-O [8] were implemented. Two recommendations that should be included in a future system if it is to meet the needs of the SAR specialist are:

- automated control of the gate range (pp 22-23);
- automated control of the focus (p 24).

In addition, there are several other design concepts that would be desirable:

- toggle switches on the sensor control panel to provide tactile feedback (p 24);
- auto-tracking of both the AGTV and the thermal IR imager (p 19);
- a status page overlay to allow the operator to quickly review the system parameters (p 29);
- intelligent support to set the gate width during poor weather conditions (p 23).

With the exception of the last item, the above recommendations arose out of the task analysis and were implemented and evaluated in the rapid prototype. The need to support the selection of gate width was identified in the ALBEDOS human factors evaluation [3], but no design concepts were developed in the ELVISS HEDAD-O.

Proposed design concepts

Based on evaluations of the software prototypes, the ELVISS field trial, and empirical studies, some changes and additions to the proposed design for ELVISS are recommended. Since these

are new recommendations, their usefulness needs to be evaluated through implementation in the rapid prototype and in future field trials. Implementation is subject to technical and design constraints. There is sufficient evidence to indicate they are desirable and in some cases imperative. They include:

- allowing the operator to access menu items with either the function keys or the trackball (pp 27-28);
- incorporating or simulating a continuous pulse mode for the laser rangefinder (p 25);
- integrating the controls to change the pulse width and the beam diameter of the laser illuminator (p 22);
- developing a display that integrates the sensors' vertical and horizontal direction (pp 18-19);
- making certain that the sensor images utilize the full dynamic range of the monitor p 32);
- using a thermal imager with a wide FOV of at least 20 degrees (p 29);
- adding a rapid zoom out capability on the AGTV (p 24);
- increasing the number of images that can be captured (p 31);
- allowing operator control of the moving map's brightness (p 26).

Further research and development

In addition, there are several general design concepts that require further investigation. In some cases, the investigation could take the form of an analysis of options. In other cases, laboratory and field research may be necessary to define the direction for future technical development of multi-sensor surveillance systems. The following investigations are recommended:

- Develop and evaluate methods for handling the stored images to allow the operator to store as many images as desired and to easily access previously stored images in a high vibration environment. The method should avoid the requirement for manual deletion of images and not clutter the moving map with a large number of contacts. One approach would be an intelligent agent that monitors the time that images were stored or last accessed and hides the contact numbers for old images. In addition, the agent could monitor where the operator is searching and display contacts for images that are in the immediate vicinity (pp 31-32).
- Investigate the value of the auto-slew in a high vibration environment with a low resolution, moving map. This would have to be investigated though a field trial since it is difficult to simulate a high vibration environment. However, the rapid prototype could be used to evaluate the effect of joint manipulation of the hand controller and the trackball on slewing accuracy as a function of map resolution (p 19).
- Investigate the impact of implementing an auto scan function on target detection, workload, and vigilance. This study could be carried out with the rapid prototype (p 20).

- Investigate methods for optimizing the moving map (p 30). Studies should include, but not to be limited to:
    - evaluating colour and brightness coding schemes to ensure information on the map is visible but does not interfere with the primary search task;
    - determining the best trade-off between resolution and context for the moving map;
    - investigating the utility of integrating the sensor images and the moving map;
    - investigating alternatives to a two dimensional digital moving map.
- Investigate the impact of an auto detect capability on target detection and workload (p 30).

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Conclusion

Modern technology, such as embodied in ELVISS, offers tremendous potential to extend the operator’s capabilities to search under degraded environmental conditions. However, the technology does not guarantee that the potential will be realized. Through the use of good human engineering processes, the probability that ELVISS’s potential will be realized has been increased. In the process, our understanding of the potential and the limitations of these types of systems has been improved, and several areas requiring further research have been identified.

The interface concepts described in this report are relevant not only for ELVISS, but for a wide range of surveillance systems. There are fundamental questions that need to be answered as one moves from directly to indirectly observing and controlling our environment. This project has identified many of these questions and provided some tentative answers.

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List of symbols/abbreviations/acronyms/initialisms

AGTV	Active Gated Television
ALBEDOS	Airborne Laser-Based Enhanced Detection and Observation System
ALC	Automatic Level Control
CF	Canadian Forces
CMC	CMC Electronics Incorporated (previously Canadian Marconi Company)
CRT	Cathode Ray Tube
DAR	Directorate of Air Requirements
DND	Department of National Defence
DRDC	Defence Research and Development Canada
ELT	Electronic Location Transmission
ELVISS	Enhanced Low-light-level Visible and Infrared Observation System
FRL	Flight Research Laboratory
FLIR	Forward Looking Infrared
FOV	Field of View
HEDAD-O	Human Engineering Design Approach Document - Operator
HMI	Human Machine Interface
IMU	Inertial Measurement Unit
IR	Infrared
LCD	Liquid Crystal Display
LRF	Laser Range Finder
MCP	Micro-Channel Plate
NRC	National Research Council
NSS	National SAR Secretariat

OMI	Operator Machine Interface
SAR	Search and Rescue
SME	Subject Matter Expert
VAPS	Virtual Applications Prototyping System

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(U) DRDC Valcartier has developed a multi−sensor surveillance system composed of an active imaging system (the Airborne Laser−Based Enhanced Detection and Observation System (ALBEDOS)) and a thermal Infrared (IR) imaging system. This system is called the Enhanced Low−light level Visible and Infrared Surveillance System (ELVISS). The purpose of the system is to enhance surveillance capability at night and under degraded weather conditions especially for Search and Rescue (SAR) operations. Throughout the development process, DRDC Toronto was responsible for the design of the Operator−Machine Interface (OMI) for ELVISS. This report summarizes the development of the OMI carried out under Work Unit 13da22, Operator Machine Interface (OMI) for ELVISS. The emphasis is on ELVISS' current state and includes recommendations for research and development that would further enhance the ability of the system to support SAR operations.

14. KEYWORDS, DESCRIPTORS or IDENTIFIERS (Technically meaningful terms or short phrases that characterize a document and could be helpful in cataloguing the document. They should be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location may also be included. If possible keywords should be selected from a published thesaurus, e.g. Thesaurus of Engineering and Scientific Terms (TEST) and that thesaurus identified. If it is not possible to select indexing terms which are Unclassified, the classification of each should be indicated as with the title.)

(U) ALBEDOS; ELVISS; Human Factors Engineering; Human−Computer Interface; active imager; thermal imager; airborne; Search and Rescue; SAR; surveillance; low−light level TV

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